



Image Science and Analysis Group  
XI4\Exploration Science Office



# **Soyuz Inspection**

## **ISIW-2017**

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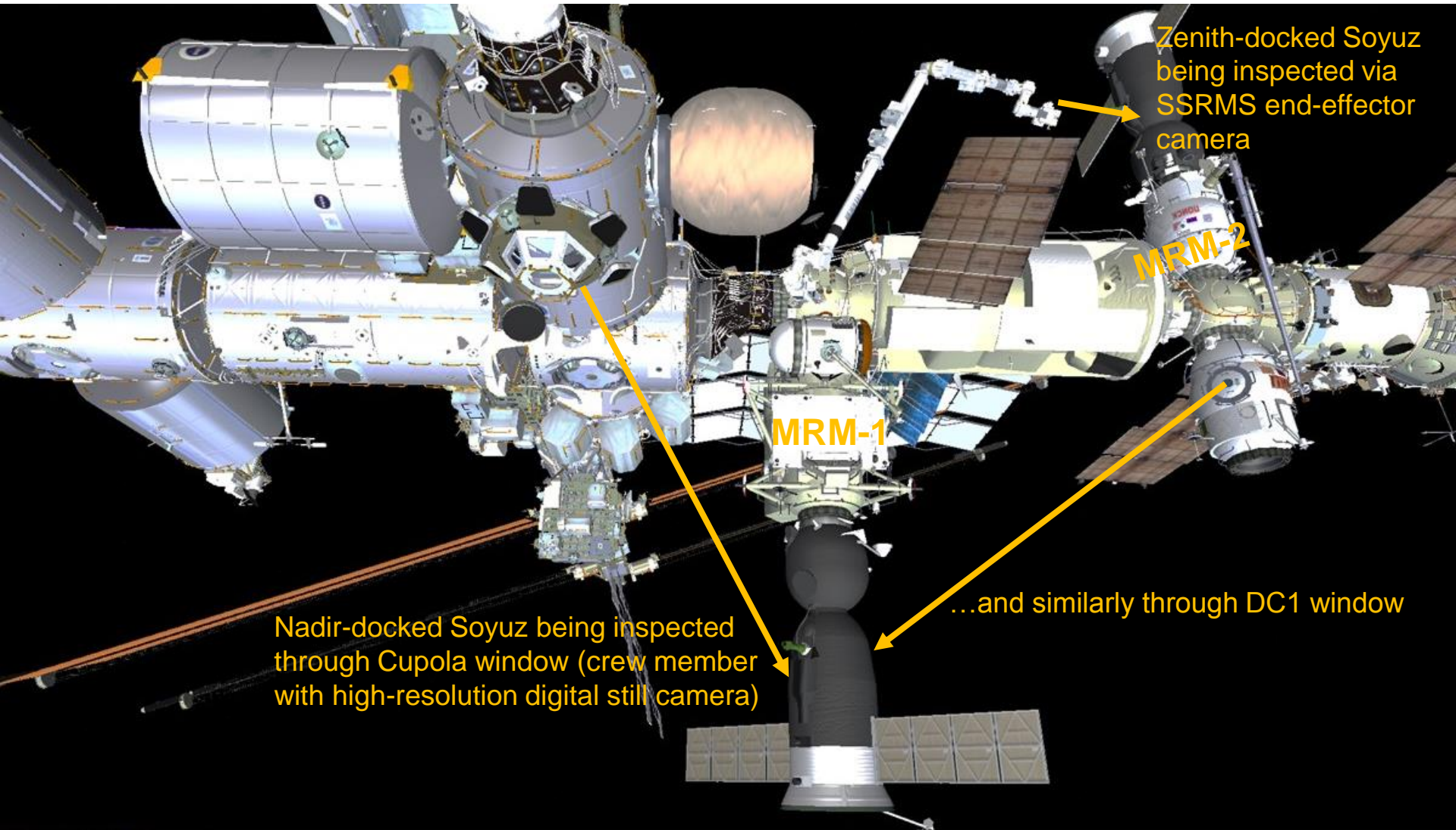
# Imagery Inspections of ISS-docked Soyuz



- Purpose
  - Mitigate MMOD risk through imagery inspection of Soyuz
- Assumptions
  - MMOD entry holes 3mm in diameter or larger may lead to catastrophic failure of Soyuz Descent Module during reentry.
  - Approximately 80% of risk is incurred on the velocity-vector surfaces of the zenith and nadir-docked Soyuz
- Inspection Approaches
  - Image from fixed camera on ISS truss
    - Historically standard-definition video
    - Recently augmented with high-definition still and video imaging capability at CP8 and CP9.
  - Image through windows (Cupola and DC1)
  - Image from SSRMS end effector camera
  - Compare regions of interest with damage sample images and with preflight images if available, and report to ISS management.



# Soyuz Inspections



Zenith-docked Soyuz being inspected via SSRMS end-effector camera

MRM-2

MRM-1

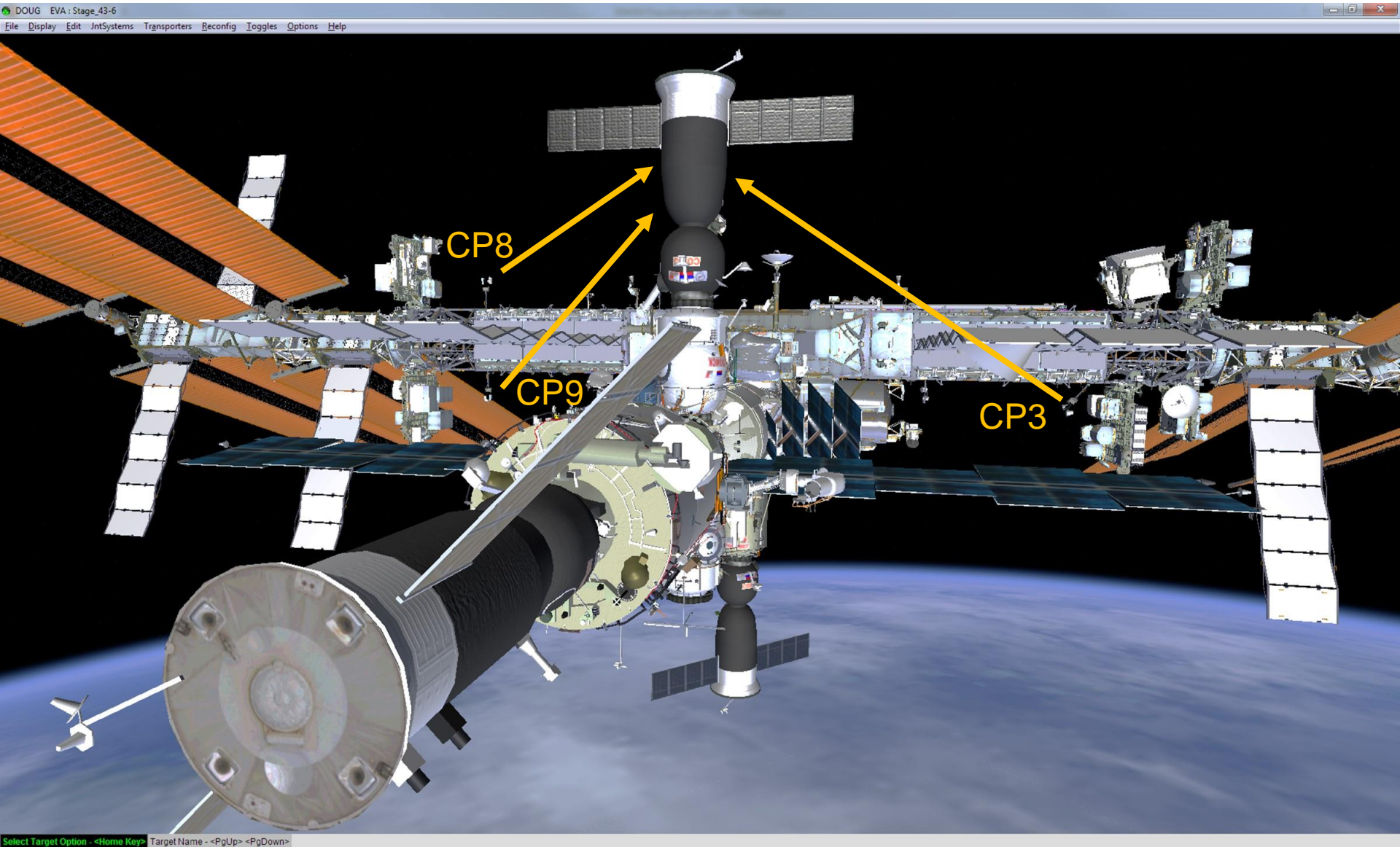
Nadir-docked Soyuz being inspected through Cupola window (crew member with high-resolution digital still camera)

...and similarly through DC1 window





# Zenith-docked Soyuz Observed from 3 Fixed Camera Positions





# Estimated Detection Resolution: Docked Location vs Survey Method

(future docking location)

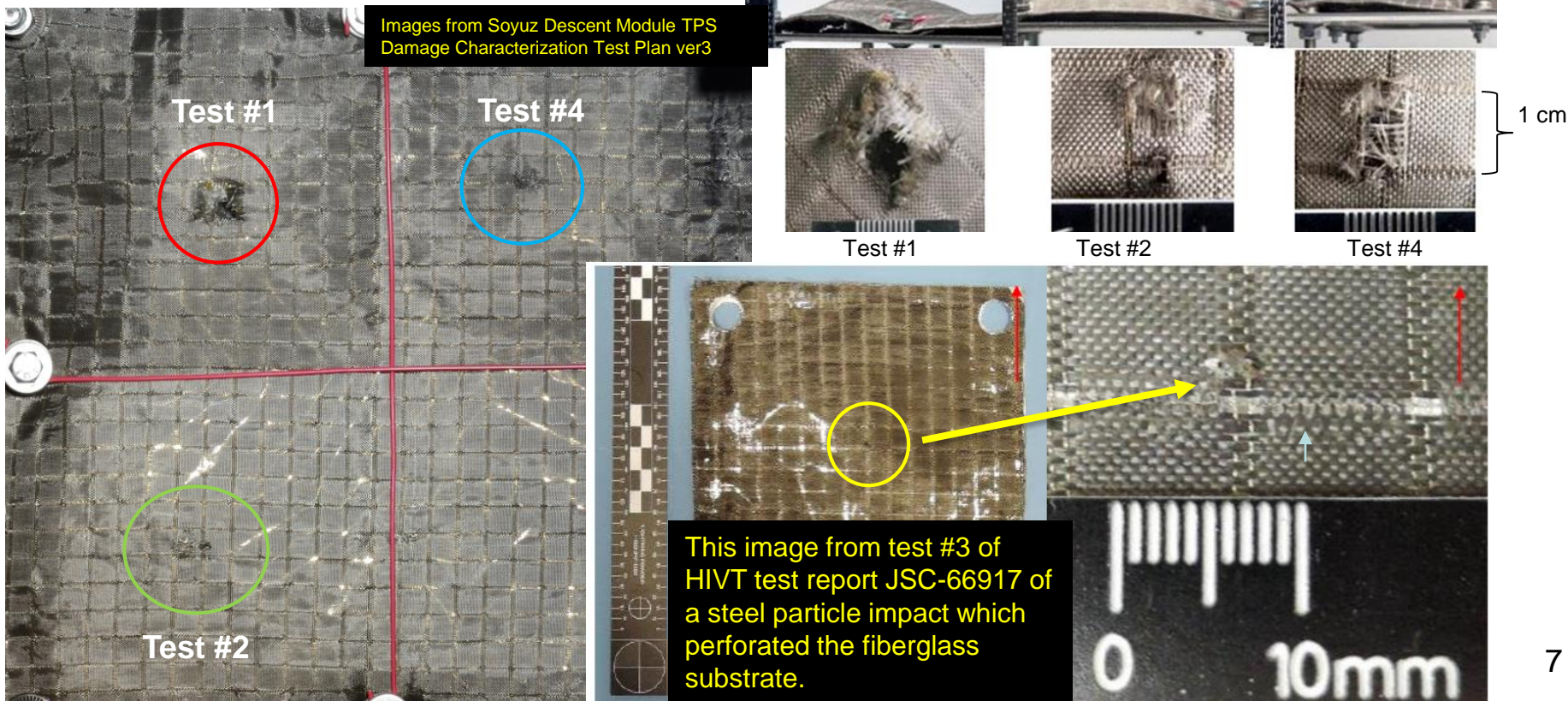
Docked Location →	MRM-1	MRM-2	MLM
Survey Method ↓	Viewable Soyuz surface and detectable resolution		
External TV Cameras (SD)* 78'-96'-118'	Fwd, 31 mm	Fwd, 39mm	Fwd, 47 mm
External TV Cameras (EHDC)* 78'-96'-118'	Fwd, 1.9 mm	Fwd, 2.3 mm	Fwd, 2.9 mm
IVA Handheld (incl. scratch pane) MRM1 Cupola 35', DC1 44', MLM Cupola 84' SM9 69'	Most, 1.6, 1.9 mm 400 mm lens	N/A	Most, 3.9, 2.2 mm 400, 800 mm lens
SSRMS LEE from Node2 or Lab PDGF MRM1 ~15'/6.5' MRM2 81'/50' MLM 65'/56'	N2 6.2mm, Lab 2.7 mm	N2 34 mm, Lab 21 mm	Fwd, N2 27 Lab 23
SSRMS Dextre from Node2 or Lab PDGF MRM1 ~7'/5.5' MRM2 68.5'/40' MLM 53'/45'	N2 2.9 mm, Lab 2.2 mm	N2 29mm, Lab 17 mm	Fwd, N2 22 Lab 19 mm
IVA Handheld (no scratch pane) MRM1 Cupola 35' DC1 44' MLM Cupola 84' SM9 69'	Most, 0.8, 0.9 mm, 800mm lens	N/A	Most, 1.9, 2.2 mm 800 mm lens
SSRMS LEE from FGB PDGF MRM1 6.5' MRM2 6.5' MLM 30'	All, 2.6 mm	Fwd**, 2.6 mm	Fwd, 12 mm
SSRMS Dextre from FGB PDGF MRM1 5.5' MRM2 5.5' MLM 19'	All, 2.2 mm	Most, 2.2 mm	Fwd, 7.9 mm
EVA handheld	All	All	All
^Color coding by <u>operational impact</u> Minimal Small Moderate Large Very Large *Easy to implement early/late comparison	^ Color coding by <u>likelihood of detecting ~3mm ROI</u> Very High (see fine stitching) High Moderate Low Very Low ** Est. able resolve stitching in some places, but need testing.		



# Window-based Inspection



- Regions of interest (ROI) are observations of potential configuration anomalies or something different in the appearance on the Soyuz MLI blanket which could be MMOD impact damage.
- The expectation for the appearance of MMOD damage is based upon hypervelocity impact tests on a sample of Soyuz MLI blanket as shown in photos below.
  - The goal is to positively confirm or clear an observation as an MMOD strike by acquiring imagery with resolution sufficient to resolve fibers or weaving pattern in and around the suspect sites.
- Analysts review imagery for changes in contrast or color and report ROI which may be more than a stain or shadow and have a dimension larger than about 3mm (assumed minimum critical damage size).



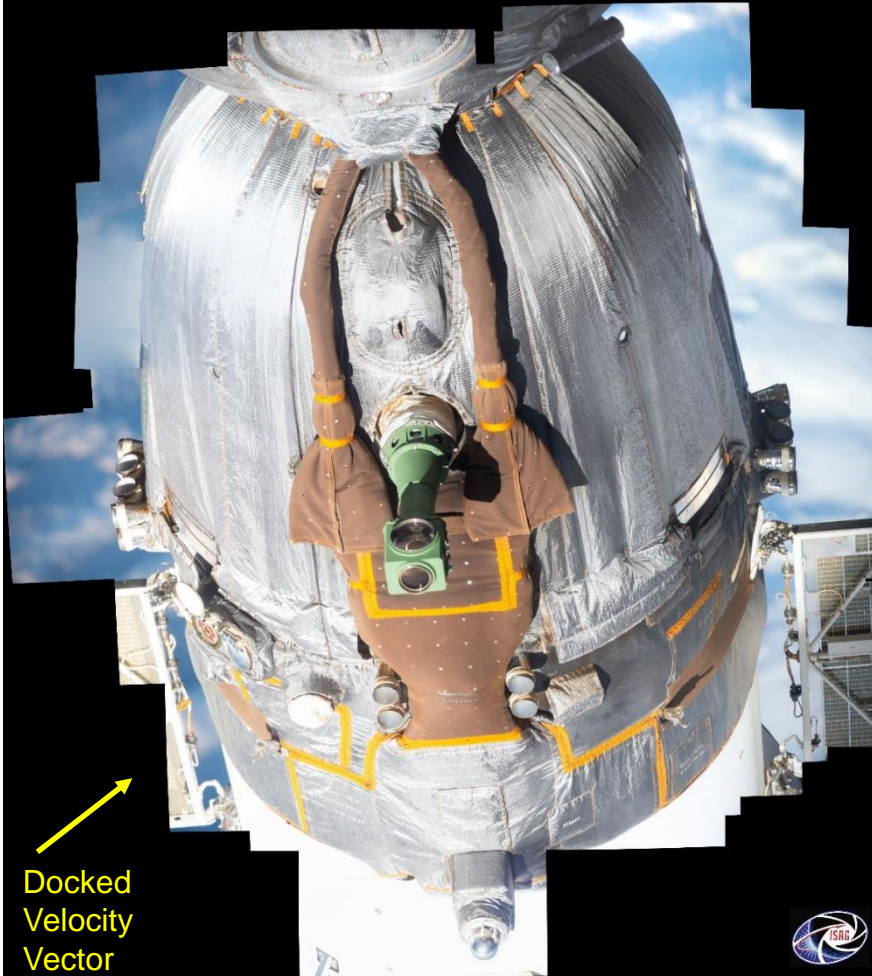




# Mosaics of 47S Descent Module Images

## Cupola Window 5

47S Soyuz - MRM1  
Nikon D4 50-500mm @ 500mm  
October 4, 2016



## Docking Compartment Window #1

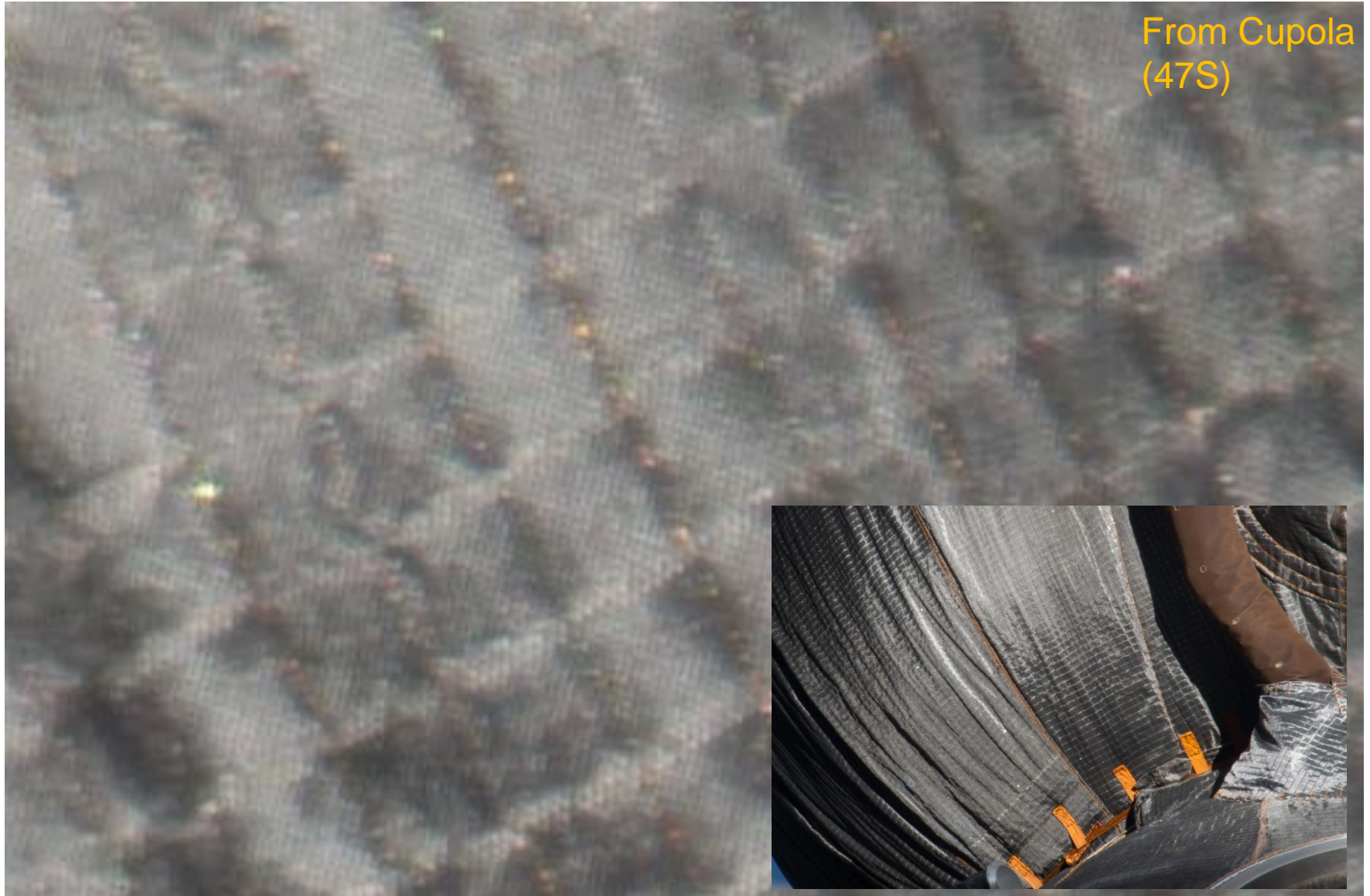
47S Soyuz - DC1  
Nikon D4 50-500mm @ 500mm  
October 4, 2016







# High-resolution Photo: MLI Stitching Visible



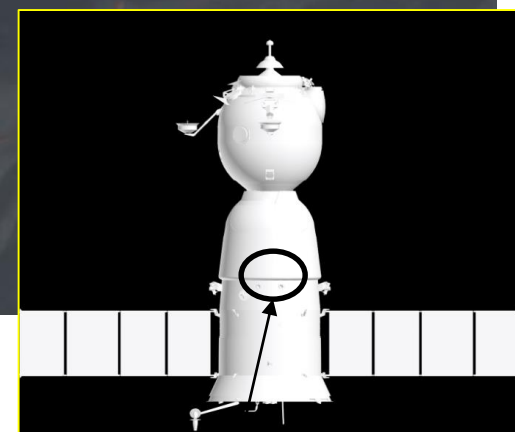
From Cupola  
(47S)



# Area of Interest #1

## Potential MMOD strike on Descent Module Surface

photo # iss049e028284

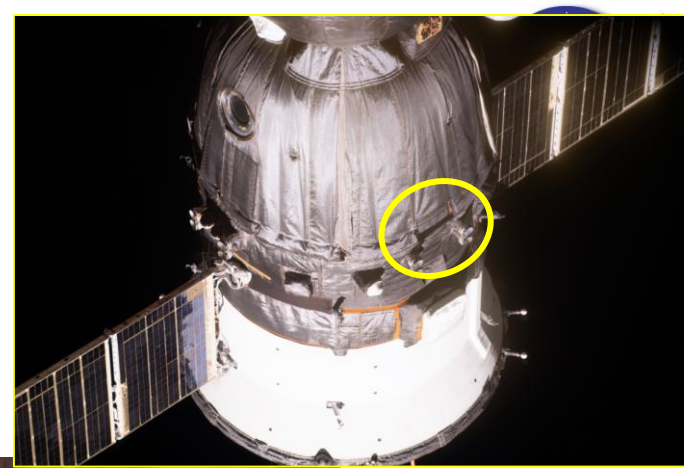


Approximate AOI Location





**A comparison with a very similar crew photo of AOI #1 region taken during docking approach could not confirm that AOI #1 was present on July 9.**



iss048e024607



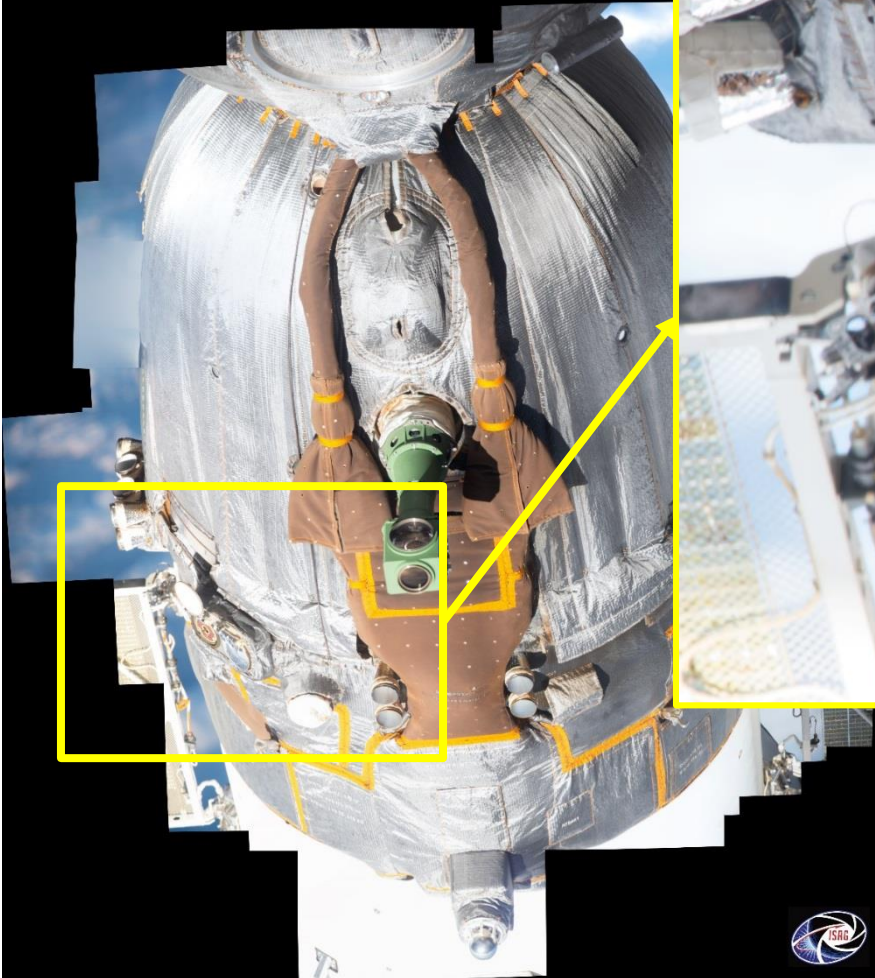




# Open Valve Cover

iss049e028232

47S Soyuz - MRM1  
Nikon D4 50-500mm @ 500mm  
October 4, 2016



Images of 47S from July 14 and subsequent also show this valve cover open. No images of this region prior to July 14 were found.





# SSRMS-based Inspection



# Survey Imagery Summary

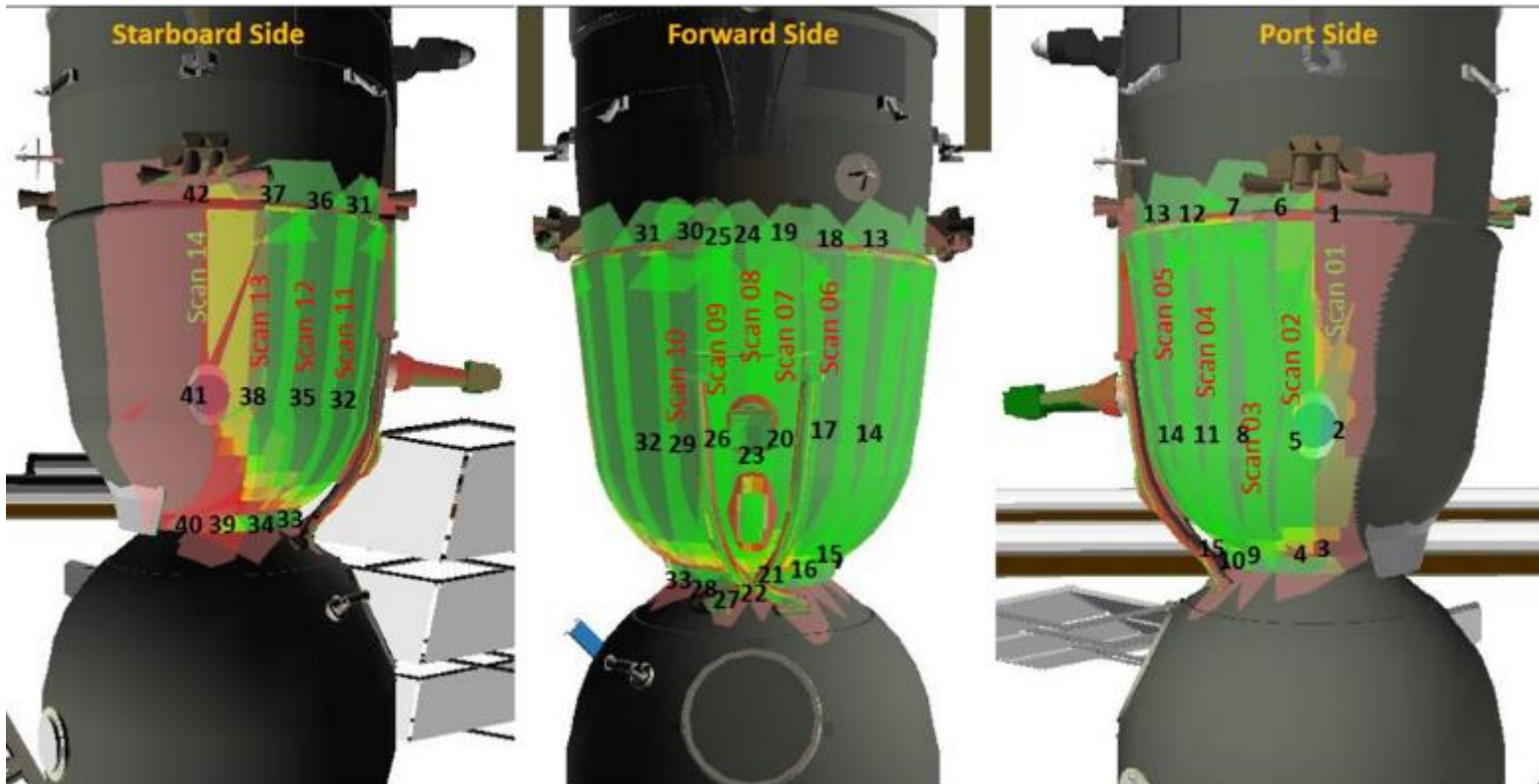
- On August 28, 2016 ROBO performed a video survey of Soyuz 46S docked at MRM2 using the SSRMS end effector camera.
  - The camera to descent module surface distance varied from 7-9 feet at the nadir end and 11-13 feet at the zenith end to remain outside the Soyuz departure corridor.
  - Camera zoom was set slightly less than maximum (90%) to facilitate manual focusing.
  - Detectable resolution was approximately 5mm
    - Smaller features are detectable in areas of high contrast





# SSRMS Survey Coverage

- 14 vertical scans were completed, providing 100% coverage of the velocity vector facing hemisphere.
  - Approximately the first half of scan 1 (port side) was not viewable due to sun glare in the lens.
  - A very small portion of scan 13 (starboard side) was not useful due to shadow and video compression loss.

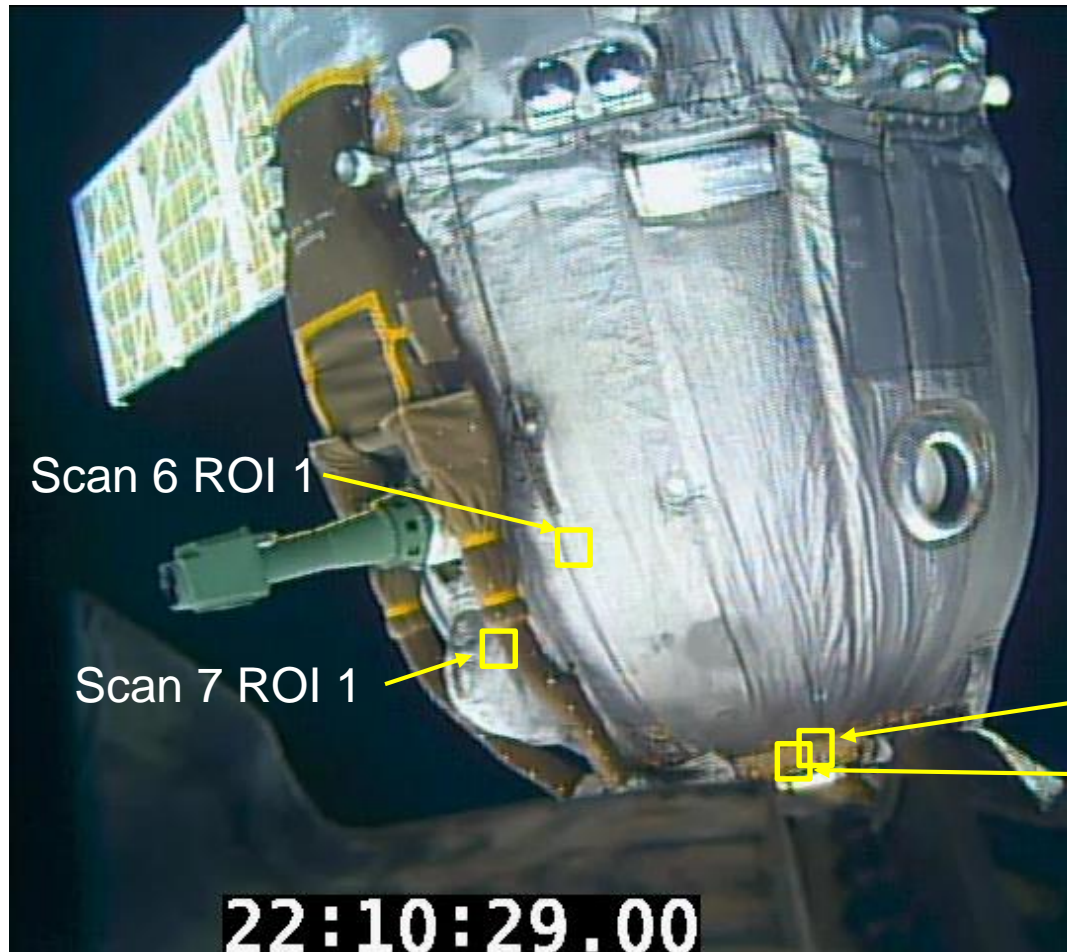


↓  
Nadir  
MRM2

Green is viewing incidence of < 35°, yellow 35°-45°, and red is > 45°.



# Port Side Overview



Scan 6 ROI 1

Scan 7 ROI 1

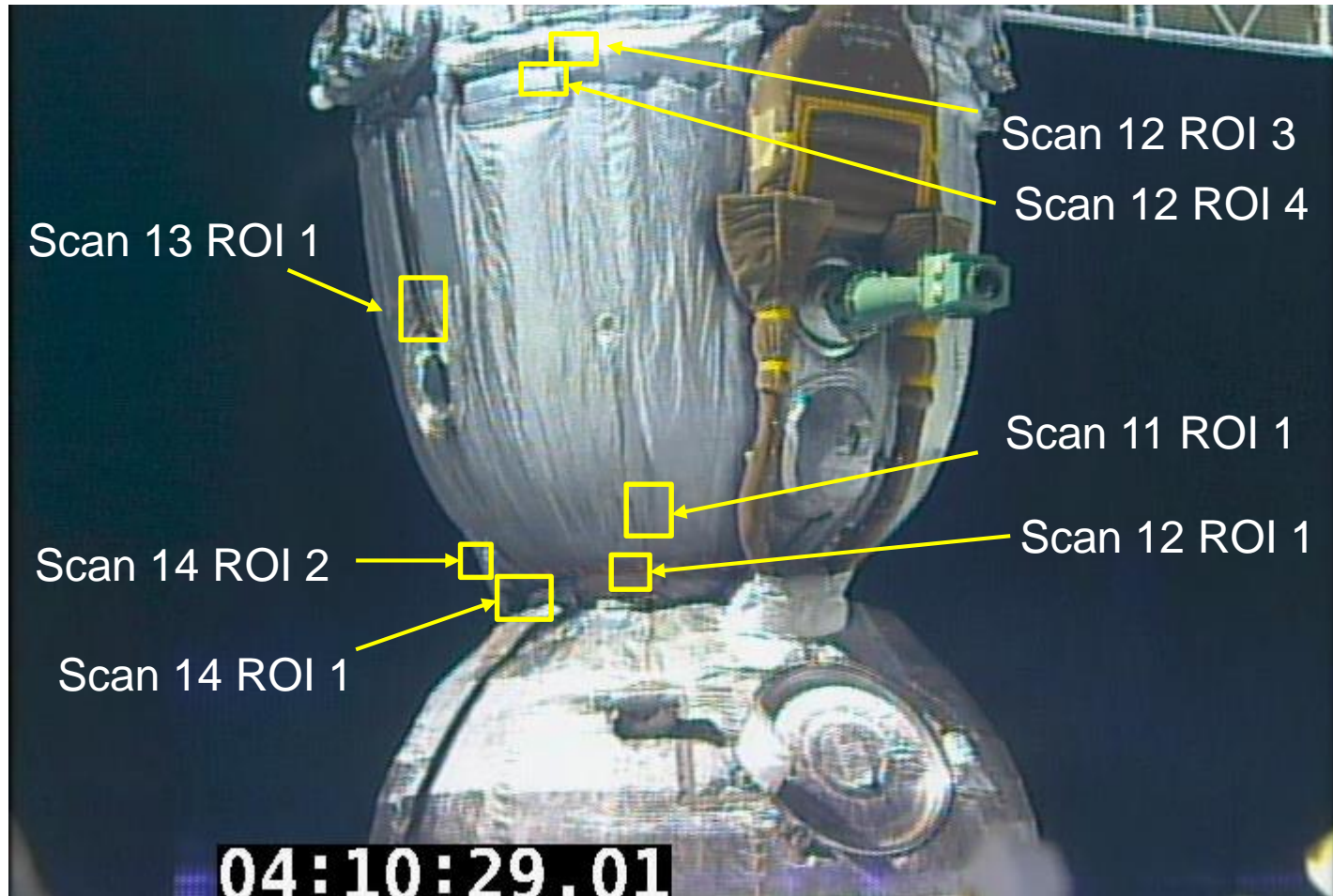
Scan 3 ROI 1

Scan 3 ROI 2

22:10:29.00



# Starboard Side Overview







# Scan 3 ROI 1 and 2

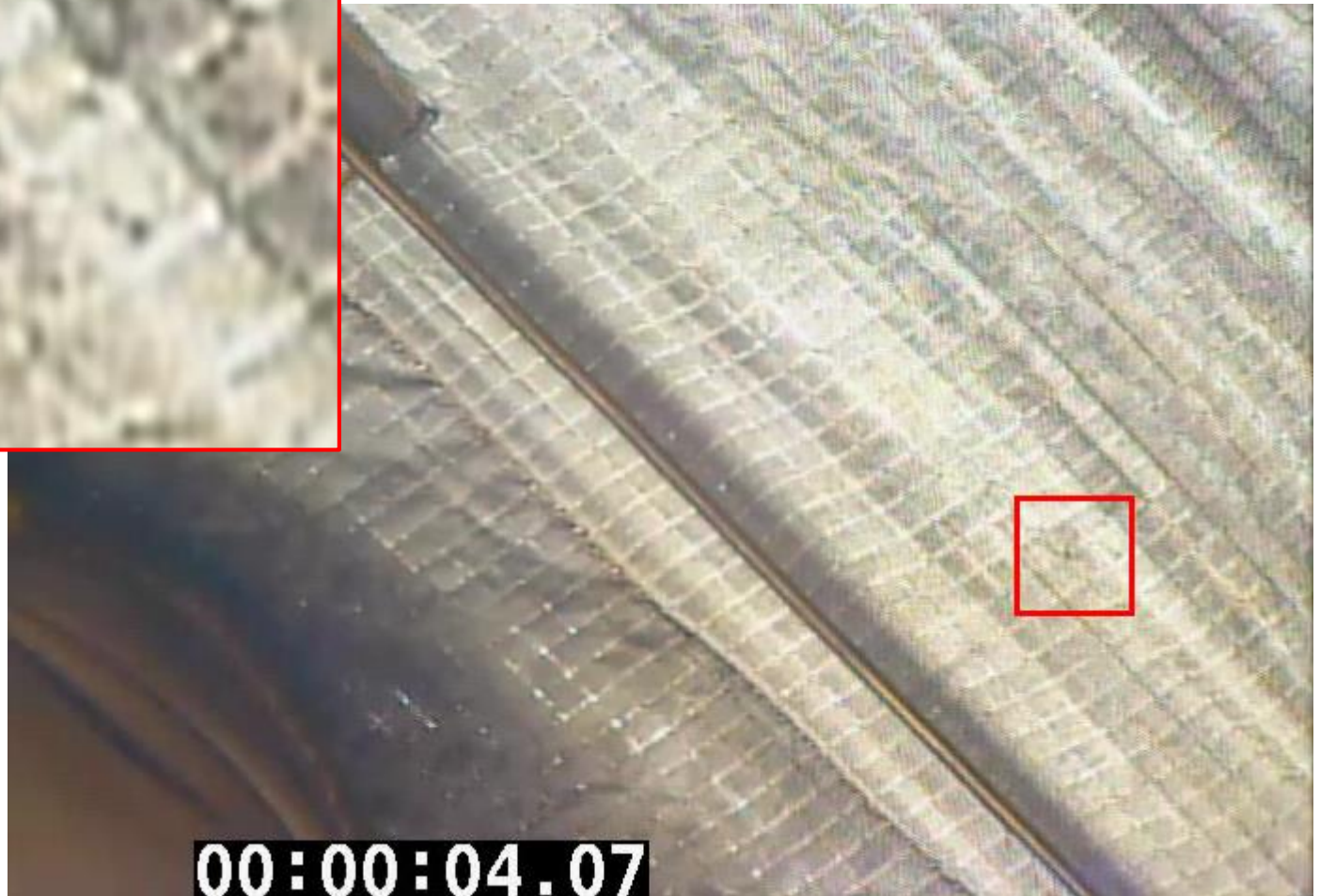
Black spots, < 3mm diameter





# Scan 6 ROI 1

Black spot, ~ 2.4mm x 1mm





# Scan 7 ROI 1

Black spot, ~ 2.2mm x 1.7mm







# Scan 11 ROI 1

Black spots, ~ 5.4mm and 3.8mm diameter





# Scan 12 ROI 1

Black spot, ~ 1.8mm diameter







# Scan 12 ROI 3

Black spot, ~ 2.8mm x 3mm



02:44:14.07





# Scan 12 ROI 4

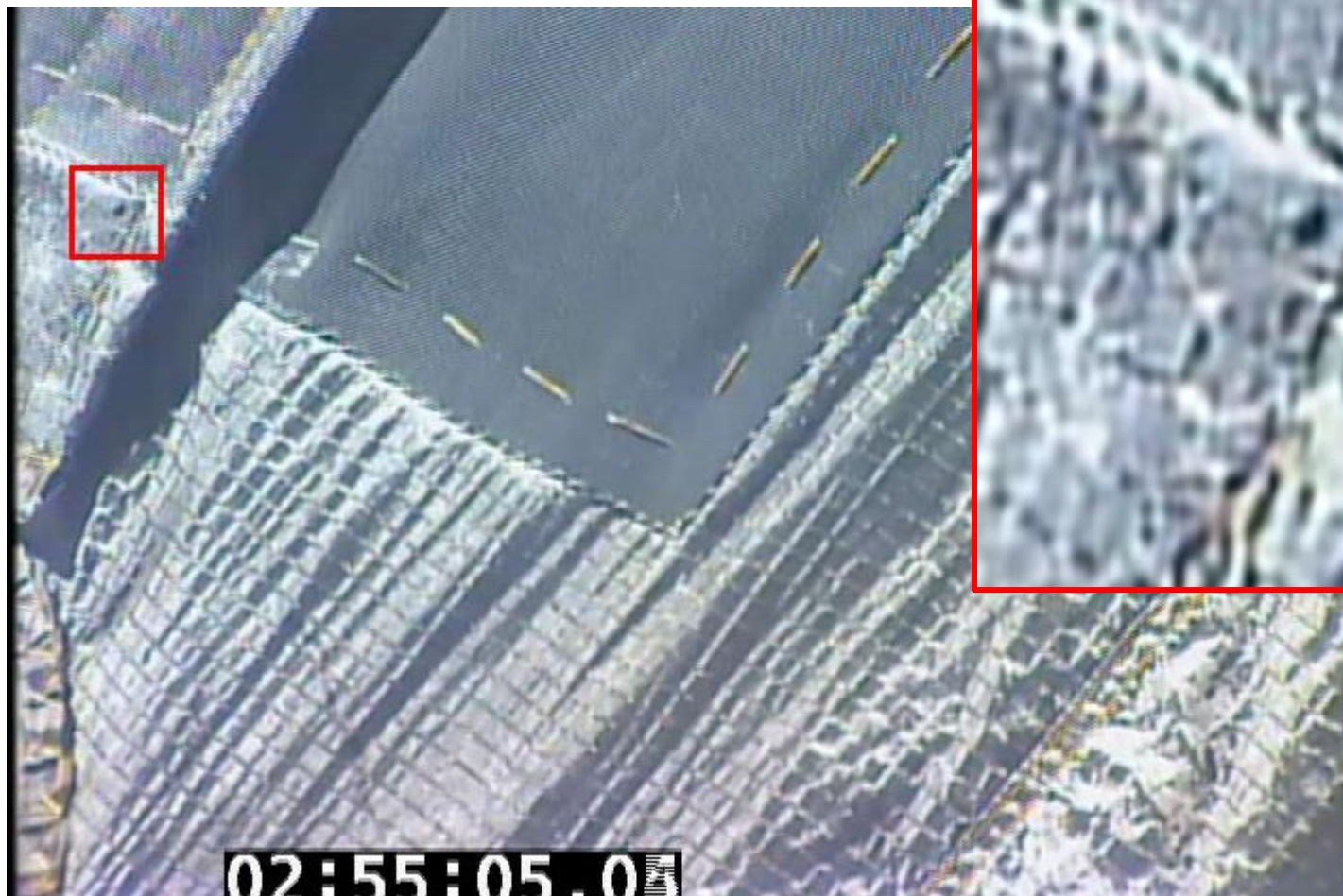
Black spot, ~ 3mm





# Scan 13 ROI 1

Black spot, ~ 3.5 x 4.9mm







# Scan 14 ROI 1

Black spot, ~ 5.3mm diameter



03:05:11.02





## Scan 14 ROI 2

Black spot, ~ 2.4mm diameter





# Issue: Stitch Aliasing







# Issue: Loss of Detail in Shadows



Loss of detail in shadows.  
Image compression issue?

02:59:00.17

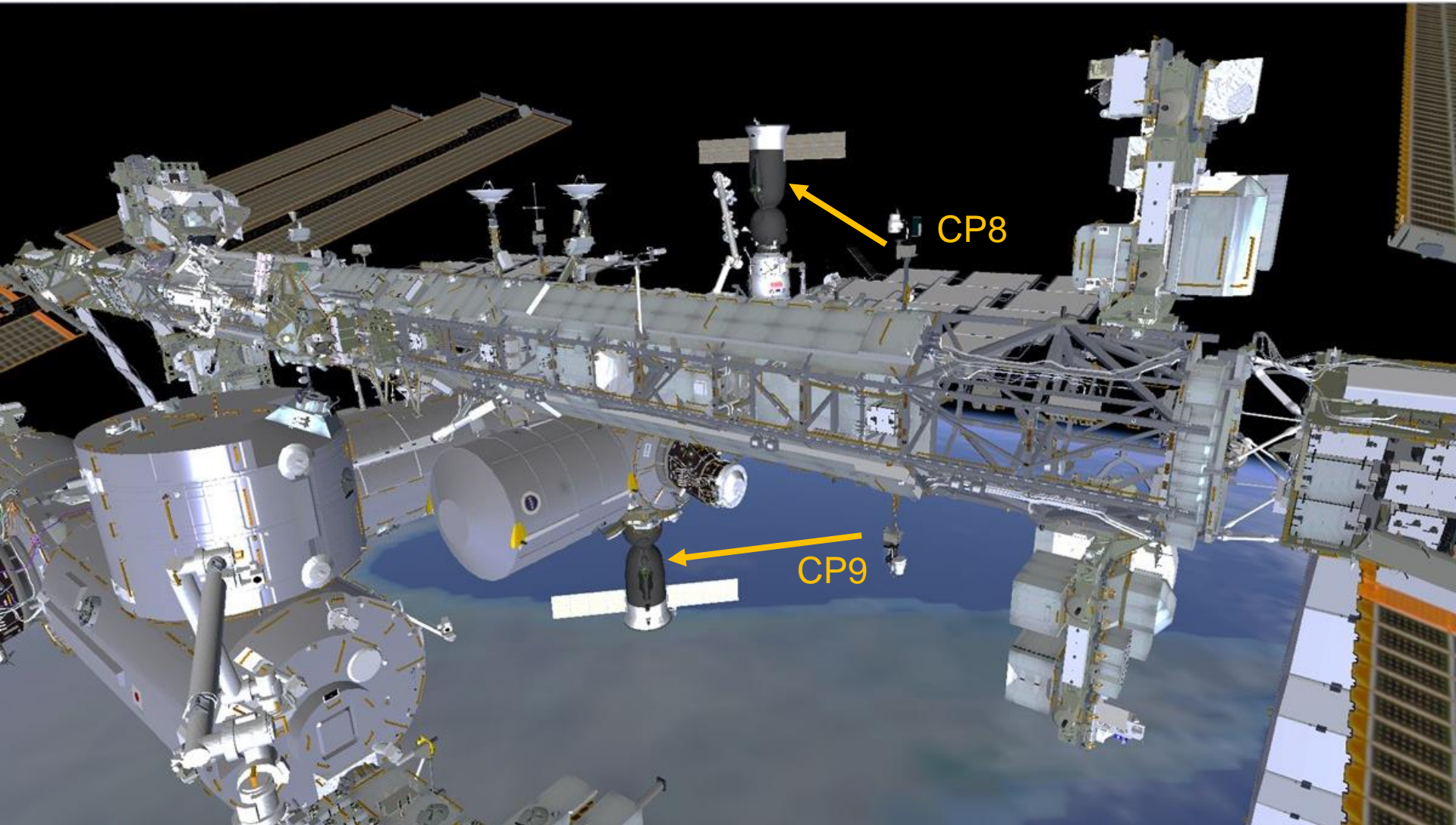




# Fixed-camera-based Inspection



**Zenith- and Nadir-docked Soyuz, each being observed from an external, fixed camera position**





# Fixed Camera Imagery from Truss



View of zenith-docked  
Soyuz (44s) from  
standard-definition  
video camera at CP8

049 18:29:56.273